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MECHANICAL PROPERTIES DATA FOR METALS AND ALLOYS:

Status of Data Reporting, Collecting, Appraising, and Disseminating

Panel on Mechanical Properties Data for Metals and Alloys

Numerical Data Advisory Board

Assembly of Mathematical and Physical Sciences

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National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PANEL ON MECHANICAL PROPERTIES DATA FOR METALS AND ALLOYS

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NUMERICAL DATA ADVISORY BOARD

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PREFACE

The mechanical properties of metals and alloys are of increasing importance to many groups in industry, academia, and government. Data for these properties are used to design parts, structures, and machines for use by everyone in the nation. This includes items from small, hand-held tools to powered equipment, transportation vehicles, earth-moving equipment, boats, bridges, and buildings.

Mechanical-properties data are important not only to assure proper performance but also to assure reliability and safety. Some items may be used only once, but others may be in use for decades (such as buildings, bridges, and generating stations).

Mechanical-properties data for materials are also significant in all types of manufacturing processes. The mechanical properties include an entire range of static strengths and cyclic stress-strain to creep, fatigue, and impact. The assessment of numerical values for many of these properties is dependent on test methods used, in contrast to determination of hard, scientific values, such as the speed of light. The mechanical properties for the metals and alloys being used are very much dependent on chemical composition as well as on thermal and mechanical history leading to strains, dislocations, vacancies and other imperfections. Therefore, in order to be of use in the design and manufacture of products, the range of property values for a given metal or alloy is essential. This, then, distinguishes a major difference between the assessment of mechanical properties of metals and alloys and the evaluation of chemical and physical property data.

The request for this study, conducted by an Ad Hoc Panel of the Numerical Data Advisory Board, was made by David Lide of the Office of Standard Reference Data of the National Bureau of Standards. His request to the Numerical Data Advisory Board was for a study of the role of the Office of Standard Reference Data in regard to the mechanical properties of metals and alloys.

The objective of the study was to determine if the OSRD had a role regarding data activities for mechanical properties of metals and alloys and, if so, to make recommendations as to what the role should be.

To explore this question, the Panel was formed with representatives from many areas of industry and academia. A fact-finding meeting was held where a much larger group of representatives from other industries, professional societies, trade organizations, and government departments were asked to present their needs and uses of mechanical property data for metals and to establish their current position as to the availability of these data.

From this fact-finding session, it was obvious that the uses, needs, and availability of data were quite diverse and that many people were involved in their measurement, collection, dissemination, and use.

This general report assessing the status and needs in this area is a product of this study. In its deliberations, the Panel considered the international aspects of mechanical-property data compilation and dissemination. General observations and recommendations are made for issues that need attention both on the national and international levels.

The Panel wishes to express its thanks to those who presented information to the Panel and aided in its deliberations. Appendix A is a listing of the participants. The Panel greatly appreciates the aid of the Executive Secretary of the Numerical Data Advisory Board, Cynthia Carter, for establishing the Panel, arranging meetings, and in the preparation of the report. It also wishes to express its thanks to Linda Popp and the Word Processing Group at the Deere & Company Technical Center for the efficient preparation of this document.

This study received support from the Office of Standard Reference Data, Department of Defense, National Science Foundation, and the Department of Energy.

James A. Graham, Chairman
Panel on Mechanical Properties Data
for Metals and Alloys

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RECOMMENDATIONS ON MECHANICAL-PROPERTIES DATA BASES FOR METALS AND ALLOYS

The Panel notes that the field of mechanical properties is complex because of the greatly diverse needs of the data providers and users as well as those problems encountered in the development of standard test methods, material properties definitions, appraisal procedures, and dissemination. A large number of groups are active in the measurement, collection, appraisal, dissemination, and use of mechanical properties in industry, academia, government, and trade and professional organizations. To these groups the Panel makes the following recommendations:

1. There is a continuing need for the organizations concerned with mechanical properties cooperatively

(a) To develop and improve the uniformity of test methods and data reporting;

(b) To develop definitions of nomenclature and properties;

(c) To develop property data appraisal procedures;

(d) To disseminate data including those evaluated in the process of developing test methods;

(e) To provide lists and disseminate information on test methods, data reporting, measurement standards, definitions, nomenclature, and appraisal procedures;

(f) To coordinate data efforts and assess data needs through organizing active committees, symposia, conferences, workshops, and other methods;

2. The above recommendations are a result of U.S. national considerations. However, the situation is even more urgent on an international level. Large amounts of data that are being generated in other countries are, in effect, lost to the U.S. community because of a lack of uniformity of definitions of nomenclature and property, of test methods, of material identification and other criteria for data reporting, and of appraisal and data analysis procedures. The eventual development of a broad international data system for mechanical properties of metals and alloys will not become feasible in the future if such international uniformity is not developed first. It is recommended that an international coordinating body be established to address the development of international uniformity upon which an international system could be built. Technical and professional societies and trade associations, such as the International Standards Organization, could play a significant role in the international development of a worldwide system.

3. The Panel strongly recommends that mechanical-properties data be addressed through the establishment and maintenance of several specialized data banks developed by technical experts, rather than by a single all-encompassing one. Such specialized data efforts should be coordinated. The present data-base management system being developed by the Metals Properties Council and the data programs at Battelle, Oak Ridge National Laboratory, and industrial and other organizations should be continued as a part of such a coordinated system.

4. The abstracting services, professional and technical societies, and trade associations listed in Appendix B, provide an excellent service in identifying publications containing mechanical-properties data. Data publishing, and their abstracting, indexing, and dissemination, should be vigorously continued.

5. Consideration is needed on legal responsibilities for the data and their reliability. The management of a data base cannot be held responsible for all the uses or any catastrophies resulting from misuse of the data. Clarification of legal responsibilities may promote the release of data currently held privately. The use of data from copyrighted documents and the effects of copyrighting data bases must be explored in connection with restricting the flow of data.

6. Exploring the constraints of data contained in government-sponsored reports and data bases is considered to be worthwhile on both the national and international level.

7. With the advent of computer-aided manufacturing and automated processing, data bases must include the mechanical properties and test methods that have become increasingly important in the planning of manufacturing processes and in the control of these processes to assure continuous quality production.

8. More emphasis should be placed on developing data bases for use in advanced analytical techniques that predict the behavior of materials in the end product.

1. INTRODUCTION

The Panel on Mechanical Properties Data for Metals and Alloys was organized by the Numerical Data Advisory Board of the National Research Council at the request of the Office of Standard Reference Data (OSRD)* of the National Bureau of Standards (NBS). Its primary purposes were the following:

1. To advise the OSRD whether it should become actively involved in mechanical property data evaluation; if so, to what extent, which properties, and what role. If not directly involved, how should OSRD interface in areas where overlap with physical and chemical properties occurs.
2. To increase awareness of the current situation in mechanical-property data needs and evaluation activities; to increase familiarity with programs and individuals involved.

In response to this request, the Ad Hoc Panel on Mechanical Properties Data for Metals and Alloys was formed to perform a "first-round" cursory survey of ongoing activities as well as needs in industry, government, and academia and those perceived by professional societies and trade associations. The request has been interpreted in a broad sense, to address the full range of mechanical properties. In the process of determining an answer for the OSRD, this report has been assembled to provide a general survey of the status and needs in this area.

This report includes a cursory inventory of ongoing activities and programs in mechanical-properties data for metals and alloys, an assessment of needs in the areas each section addresses, and a summary of some major existing committees within various national and international organizations and professional societies.

*The Office of Standard Reference Data at the National Bureau of Standards administers the program under the National Standard Reference Data System (NSRDS), a nationwide system established in 1963, by action of the President's Office of Science and Technology, more recently strengthened by the "Standard Reference Data Act" (Public Law 90-396), which was signed into law July 11, 1968. "Standard Reference Data" are designed as appraised data for physical and chemical properties of well-defined substances and systems. OSRD was assigned the centralized coordination of the technical programs of NSRDS data centers, that are funded by either OSRD or by other government agencies. Cognizance is taken of other high-quality programs under nongovernment sponsorship, and partial support of such efforts is sometimes provided by OSRD.

The Panel held three meetings. The first of these was a fact-finding meeting held on July 2-3, 1979, at which represei atives from a wide range of industries, agencies, and academia were called together to present the current activities and needs in regard to mechanical-properties data. The agenda of this meeting is given in Appendix A.

The second meeting, on August 9, 1979, was a visit to the National Bureau of Standards at Gaithersburg, Maryland. At this meeting, the Center for Materials Science and the Fracture and Deformation Division of that Center were visited. Past mechanical-properties data programs at NBS were described, and a presentation was given on NBS materials-science data activities in materials for coal conversion plants being carried out for the Department of Energy (DOE). Possible roles and activities of the National Bureau of Standards in regard to mechanical-properties data were discussed.

At the third meeting, held on October 3, 1979, the Panel discussed its conclusions and recommendations. From the discussions at the Panel meetings, it can be concluded that mechanical-properties compilation, assessment, and dissemination are extremely diversified. This Panel report provides an overview of the most important elements or aspects of mechanical-properties data uses, availabilities, and needs and brings out some of the problems and complexities in assessment procedures and requirements, materials identification procedures and requirements, user and producer diversities, and diversities in existing compilation activities. An in-depth comprehensive assessment would require considerable additional study.

The Panel perceived considerable evidence of interest in mechanical-properties data as well as concern regarding large amounts of test data that are undocumented. Additionally, it was observed in the NRC report of the *Committee on Data Needs**, that "*The Industrial Research Institute*, Inc. (IRI), with 243 member companies in the aggregate represent a major portion of the total industrial R & D effort in the United States. Of the 75 companies responding to a questionnaire, over 50 percent indicated a need for mechanical and acoustic properties of materials, 65 percent could use data compilations and 48 percent could use computerized data banks."

The various sectors of industry, academia, and government are in need of good data, in addition to those currently available to them. Some sectors, such as the Department of Defense (DOD), are quite well advanced in their materials-properties knowledge and data systems, whereas others have more recently recognized the need for data and are developing data programs. An example here is the Department of Energy (DOE). Whereas this agency has already had some information activities, it has more recently identified the need for additional property data on alloys for the development of new technologies for power generation. This need for reliable data is in diverse areas, including nuclear energy, both light-water and liquid-metal fast-breeder reactors, coal gasification and liquefaction, and solar energy.

Data collection, assessment, and dissemination is done mostly by government and private industry. The aircraft and space industry, the DOD, and the National Aeronautics and Space Administration (NASA) have in common many

*National Needs for Critically Evaluated Physical and Chemical Reference Data, Committee on Data Needs, Numerical Data Advisory Board, Assembly of Mathematical and Physical Sciences, National Research Council (National Academy of Sciences, Washington, D.C., 1978).

interests in uses of data. These as well as other government agencies sponsor a number of mechanical properties data centers. A number of sectors of industry have also found it necessary to develop good data on mechanical properties as a means of advancing the development of their industry. One notable example of this is the gas-turbine industry, which needed to generate good reference data in order to develop the gas turbines. Generally, data centers specialize in the materials and properties of particular interest to their applications, including high-strength steel, aluminum, titanium, and super alloys, as well as ceramics and composite materials.

Data needs for transportation present as many differences as similarities. Materials include those used in large civil-engineering-type of structures such as highway and rail bridges, pipelines, and ships. These structures are made of steel manufactured in high tonnages and as economically as possible. By various means, the Department of Transportation (DOT), our maritime, and other U.S. Government organizations control design requirements in each of these areas. Often it appears that the properties of the commonly used steels are reasonably well known. The current concern is an economical means of ensuring the uniformity and quality of these products. The failure of a critical part in a bridge, a plane, or other transport structure presents a risk to human life. One part of the shipping area, for example, is concerned with the transport and storage at cryogenic temperatures of liquid natural gas, a hazardous material. Development of such specialized safe transport requires special data considerations.

For the automotive ground vehicle and railroad industries, data generation, collection, assessment, and dissemination is controlled almost completely by the trade associations and the technical societies. Some of the data and procedures developed by the automotive and ground vehicle industries can be considered technically advanced.

Some trade associations and professional societies have paid particular attention to the collection, assessment, and dissemination of mechanical properties data of interest to their sponsors. One notable example is the system developed by the Copper Development Association. It provides a data base on the properties of copper, accessible on-line in three languages on an international network. Another example is the American Society for Metals (ASM). Although this organization does not provide on-line numerical data at this time, it does provide an automated bibliographic system that presents to the mechanical-properties user community a centralized indexed source of world literature. A specialized product of this ASM activity is "Aluminum Abstracts, prepared for the Aluminum Association. Additionally, ASM provides printed handbooks and data books.

An organization that has the specific purpose of providing reliable mechanical properties data is the Metal Properties Council (MPC), established jointly by the ASM, the American Society for Testing and Materials (ASTM), the American Society for Mechanical Engineers (ASME), the American Welding Society (AWS), and the Engineering Foundation (EF). It is developing an on-line numerical data base to serve the communities represented by these societies. The Federation of Materials Societies has a standing committee on materials information. This group provides a forum in which those with diverse interests in mechanical properties of materials can cooperatively address the subject.

The measurement of mechanical properties data and their uses are complex. Broadly speaking, three different degrees of data reliability can be identified. The first is in those applications where the materials performance is pushed to its limit and where materials failure must be avoided at all cost. In this case, the scientist or engineer using the material is likely to be an expert on this material, and available handbook data may not provide the required degree of assessment and materials identification. The second is that in which a lesser degree of confidence is required, and generally verified data, as available in good handbooks or data banks, suffice. The third is where precise knowledge of the materials properties is relatively unimportant (e.g. mass-produced everyday hardware).

However, the material used in one application where the properties make little difference might be used in another critical application where extensive information is required. In order to be prepared for the future, it is desirable to have data of a particular nature on various materials so that possible uses of it can be identified as the need arises. The list of types of property information needed by all users combined is quite extensive. It is doubtful that any one material has all of its properties measured, and a special application of a given material may require extensive data on certain of these properties.

A program on mechanical-properties data assessment must also be concerned with the test environment and the end-use environment, which may present a range from low temperatures to high temperatures, corrosive atmospheres, and radiation. This wide variation of environment not only increases the complexity of the testing procedures but also in the interpretation of the property data as to how the material will function in the end-use product. Further complexities enter because of the large number of alloys that are in use and will be added to the end products in the future, as well as the wide range of thermal and mechanical histories to which these materials are subjected. This requires an extensive list of test methods, which need to be standardized for exchange of information between various organizations. One method of being able to compare results from various laboratories is the use of standard reference materials (SRMs). However, for many types of mechanical-properties tests, SRMs have not yet been developed. Development of more standard test methods is similarly required for data comparison and assessment.

There are a number of terms used in discussing mechanical-properties data that are used with various meanings by different groups even within the field. Two noteworthy words are "evaluation" and "characterization." What is meant by characterization by one group is used by another group to mean evaluation. Therefore, we have avoided these two terms in the preparation of this report. For the purposes of this report, we are using the term "appraisal" to mean that the validity of the data has been assessed and that the data represent the properties of the material being tested within a determined range of uncertainty. The term "material identification" describes the pedigree of the material which includes the conformance to standard specifications, the heat identification, the product form, the chemistry, the crystal and microstructure, the milling process, and the thermomechanical history of the material.

In the deliberations of the Panel, major sources of mechanical properties data were identified. A paper entitled "Data Sources for Materials Scientists and Engineers" by J. H. Westbrook and J. D. Desai, published in the Annual Review of Materials Science, Volume 8, pp. 359-422, 1978, presents an extensive

survey of sources of materials data. This publication includes handbooks, directories, data centers, data journals, data compilations, on-line computer data bases, guides to materials information, and referral centers where materials information can be obtained. However, when one attempts to identify sources of mechanical properties data in this review, the list becomes rather small. Therefore, this Panel has identified and listed in Appendix B a number of data sources on mechanical properties of metals and alloys concerning abstracting services, numerical data compilations, computerized numerical data bases, and international data activities.

The content of this report is a survey of the current situation and the needs for mechanical-properties data as seen by the private sector, academics, government organizations, professional societies, and trade associations. The report is divided into five descriptive headings including: the uses and dissemination of the data sources, collection and appraisal, the development of standard test methods, the computerizing of the mechanical-properties data system, and a review of international activities. Each chapter contains recommendations for the engineering community as a whole about that particular subject, thus providing some guidance to the many groups concerned with mechanical-properties data.

2. DATA USES AND DISSEMINATION

Three main categories of engineering data can be identified:

1. Properties information for the general design function, including mechanical properties; physical, thermal, chemical, and nuclear properties; and possibly others.
2. Specifications information, including material, process, design, and performance specifications. Some of these require test methods for mechanical properties and include inspection and acceptance procedures as well as safety, health, and environmental concerns.
3. Purchasing information such as costs, vendors, availability, delivery dates, ordering, and shipping.

Mechanical-properties information is contained primarily in the first category but may also be needed in the second.

Uses of Data

Uses of data on mechanical behavior for the general design function include the following:

Materials Selection. These decisions are made early in the design process but periodically are reassessed as the design evolves.

Design. Establishment of the configuration and sizes of components and parts. This should take into account pertinent loading and temperature environments and strength features, such as yield, tensile, fatigue, creep, and rupture strengths.

Manufacturing and Fabrication. Each manufacturing step, including raw material selecting, casting, forging, rolling, forming, machining, heat treating, and joining and assembly, affects the final mechanical behavior and performance of a machine or structure. Thus, mechanical properties data should reflect thermomechanical history and other documentation described in Chapter 3, and the control of important manufacturing and fabrication variables required to achieve these properties. This is an area where no general approaches are available, although, for some situations, beginnings have been made. The American Society of Mechanical Engineers (ASME) Code for Fabrication of Nuclear Pressure Vessels is an example.

Processes that allow economies with no loss of quality are vigorously sought out. Thus, data that purport to allow comparison between the newer process and older ones are constantly being generated, sometimes in great secrecy (for example, materials data for gas turbine buckets and blades). In planning for categories of mechanical properties data, special provisions must be made for collection, organization and appraisal of selected properties which are different in a dynamic operation mode than in a static mode.

Life Estimation, Life Testing, and Failure Analysis. Life testing of products as well as analytical methods of life estimation form essential steps in developing and demonstrating a safe and reliable product. The quality of the data input for analytical methods has a crucial influence on the accuracy of the results. In a similar manner, when a deficiency is discovered by life testing, finding a remedy depends on knowing the mechanical properties for the replacement part.

Data Dissemination

It is evident from Appendix B that significant efforts are already under way to accomplish mechanical-properties data compilation and dissemination by a variety of government and private centers and organizations. Appendix B lists four categories of data activities: abstracting services, numerical data compilations, computerized numerical data bases, and some international data activities. The modes of dissemination range from printed to computerized as accomplished by government organizations, professional societies, trade associations, and private institutions.

A general observation of the Panel is that a broad need exists for coordinated up-to-date reliable data bases that are accessible to different types of users through the various classical and modern methods of dissemination. These data bases should be developed through a number of specialized data projects by technical experts. They should be coherent and uniform in their format, definitions, and input and output methods, thus allowing for integration into a coordinated system. Having uniformity and compatibility will aid in accumulating data that show the variation of material properties from heat to heat. The data system must include data on the effects of extreme environments that will be encountered by certain materials such as those employed in nuclear power plants, data needed for long-term applications such as in coal gasification plants, and data needed for the construction of other safe equipment and structures.

In preparing compilations of materials properties we find it necessary to address the issue of proprietary data. Some data could be made available if the originators are not identified with the data itself. Further consideration is needed on legal implications of decisions based on data obtained from a central data base. The management of the data base cannot be responsible for all the uses or any catastrophes resulting from misuse of the information.

Having data compiled, particularly with a computer, provides increased ability for the evaluation and the selection of materials, including new compositions, for a given application. The data can be used along with new, improved computer techniques, such as the finite element methods, to aid in the design of various products with the desired performance and product life. However,

there are a number of types of failures that are difficult to predict because of lack of data or lack of theories. Special emphasis should be placed upon the development and application of advanced analytical techniques. There is some concern on the part of materials specialists that particular emphasis should be placed on the interpretation of mechanical-properties data from laboratory measurements for use in the design-oriented analysis procedures, so that the design analysis methods do indeed reflect the true performance of the material in the end product.

With the advent of computer-aided manufacturing and automated processing, mechanical-properties data have become increasingly important in the planning of manufacturing processes and in the control of these processes to assure continuous quality production.

Recommendations on Data Uses and Dissemination

1. A preference is expressed for small data compilation and appraisal activities done by technical experts, integrated into a data system. This integration in turn requires uniformity and definition of input.

2. Dissemination of data should be in those modes most suitable to the particular user community. This ranges over all possible modes. Since the technical/professional societies and trade associations represent a major resource in the dissemination of new information they should be encouraged to disseminate mechanical-properties data. Abstracting policies for articles and symposium proceedings should include procedures for data flagging and data tagging.

Pending the development and on-going operation of the ultimate computerized data banks of the actual mechanical properties, compilations of references to specific mechanical properties of metals and alloys should be developed and made computer-searchable. Where possible, validated (or appraised) data should be so marked. These references should include journals, symposium proceedings, textbooks, reference books, and data sheets.

3. Consideration is needed on legal responsibilities for the data and their reliability. The management of data base cannot be held responsible for all the uses or any catastrophes resulting from misuse of the data. Clarification of legal responsibilities may promote the release of data currently held privately.

4. Many of the data expected to be incorporated into computer-searchable data banks will necessarily have to come from published sources that have a copyright restriction. It is likely that some of the computer-searchable data banks, and particularly those that have no hard-copy equivalent, will also have copyright constraints. Mechanisms should be developed for relief from the copyright, so as not to minimize restriction to flow of data.

5. More emphasis should be placed on developing data bases for use in advanced analytical techniques.

3. DATA SOURCES, COLLECTION, AND APPRAISAL

Data Sources

The original, or primary, sources of data are where tests are conducted for research and development as well as for regulatory needs. Secondary sources are organizations who solicit and collect data for further appraisal, analysis, and preparation of technical reports or papers for dissemination or use, either private or public.

Examples of principal sources of primary and secondary data are the following:

- Industries or organizations that need the data for developing new materials and for designing, manufacturing, and marketing their product.
- *Government programs* such as those under NASA, DOD, DOE, and others who need data for equipment design specifications, for safety purposes, for regulatory action, or for new development projects.
- The Metal Properties Council Programs that collect or generate data and analyze and report metal properties for industrial use.
- National laboratories working on government or industry programs.
- Research organizations, including universities, performing testing or development activities for industry or government.
- Technical societies or trade associations that sponsor programs or provide presentations of technical information for private or public interests.
- The Welding Research Council and Pressure Vessel Research Committee, who sponsor research work for industry and government.

Collection

The collection of data from all the sources requires a coordinated effort involving organizations that are technically competent in their specialized areas and are recognized as such by the engineering community. Because of possible proprietary interests in the data obtained for commercial purposes, there must be a well-understood policy on how data will be used and who has access to it.

Not only must there be better policies, but a standardized system for soliciting, reporting, and accepting data must be established for a successful collection effort. Many of the papers published in journals and proceedings

contain only the minimal data to support the paper. Some mechanism to assure on-going accessibility and retrievability can reduce the unwanted duplication of data generation. The system of data repositories, which is underutilized, is one possible mechanism.

There are several organizations that have expertise in mechanical-properties data solicitation and collection. These include the following:

- The Metal Properties Council.
- Certain government agencies, such as NASA, DOD, and DOE.
- Some trade associations, such as the Copper Development Association.
- Electric Power Research Institute (limited experience).

Appraisal

To be considered acceptable for inclusion in a data bank, data obtained by solicitation or volunteered to the data bank must be appraised. Elements of this appraisal include the following:

- Qualifications and integrity of source organization.
- Adequate identification of materials by
  - Conformance to standard specification or other adequate identification;
  - Heat identification, commercial, or laboratory;
  - Product form;
  - Chemistry;
  - Crystal and microstructure;
  - Melting, thermal, and mechanical processes.
- Completeness of test series and data.
- Description of test methods and test environment.
- Consistency of results.
- Number of heats tested.
- Assurance that tested material is representative of material in end use product.
- Format for reporting data.
- Other appropriate considerations.

As a result of the appraisal procedure, the degree of suitability of the data for further processing, analysis, and application can be established. Although reliability levels have been used as a classification system in some areas, this term should be avoided because of its implications. Some limited data may be of excellent quality but not of sufficient quantity to stand by itself. At this time, no recommendation is made for the specifics of a classification system.

Recommendations on Data Sources, Collection, and Appraisal

Through agencies supported by industry, such as the Metals Properties Council, systems and programs have evolved, based on needs and the urgency of meeting those needs. The Panel believes that up to the present, most of these

urgent needs have been met by initiatives coming from industry and certain government agencies such as DOD, NASA, and DOE. It also believes that new initiatives or increases in current activities are needed by professional/technical societies and government agencies to capture large amounts of test data generated at great cost but not stored in an analyzable, usable, retrievable form.

A major weakness hampering progress toward the development of mechanical-properties data sources lies in the lack of uniformity of data reporting, material identification, and appraisal procedures. The Panel believes that a coordinated effort should be undertaken:

- To enhance uniformity of test methods and data reporting;
- To develop definitions of nomenclature and properties;
- To develop appraisal procedures;
- To develop a policy on the access to the data and its uses.

This effort should seek coordination between government and industry and obtain input from professional societies and trade associations. Furthermore, this effort should be done as much as possible on an international level (see Chapter 6). The Panel perceives a need for strong participation by standards and data organizations such as ISO, CODATA, ASTM, MPC, and NBS in the development of this uniformity.

4. ACTIVITIES IN DEVELOPMENT OF TEST METHODS FOR MEASURING MECHANICAL PROPERTIES

Generally, the American Society for Testing and Materials (ASTM) represents the primary organization developing test methods for mechanical properties. It has done so since the Society's beginning in 1898 when it was part of the International Society for Testing Materials. As a result, this section will discuss primarily the activities of this Society. Today, with its 134 Technical Committees representing many disciplines, ASTM has the facility to identify needs for data based on service experience and technology changes. ASTM publishes annually over 200 test methods for determining mechanical properties of metals and alloys. These methods cover properties such as bend, flexure, ductility, formability, impact, hardness, stress-relaxation, tension, fatigue, fracture, corrosion, wear, shear, and machineability. These are contained in the 1979 Annual Book of ASTM Standards, Part 10, "Metals--Mechanical, Fracture, and Corrosion Testing: Fatigue; Erosion, Effect of Temperature."

In developing uniform, practical measurement and reporting procedures, certain issues must be considered: (a) the preferred test methods, (b) data developed before a test method was established, (c) parameters not covered by standard test methods, (d) needs for standard reference materials, (e) needs for standardized data-analysis procedures.

Over the years, ASTM has prepared a series of Special Technical Publications (STP) and Data Series (DS) on properties of metals and alloys. Quite often, data are generated and appraised as part of research programs preceeding the development of a standard test method.

Other organizations such as the Society of Automotive Engineers (SAE) have developed several mechanical tests, which are published in the SAE Handbook. DOD has also developed its own methods to support materials specifications. The DOD policy is to use those methods developed by voluntary standards organizations wherever possible. There are, of course, those methods developed by individual companies, which, for the most part, remain private. But the importance of these activities is whether such methods are used in developing mechanical-properties data that will ultimately be collected by data centers.

Along with tests for specific properties are the essential supporting methods, developed by ASTM, covering calibration and verification of mechanical testing machines, statistical analysis of data, and particle size measurement. These are contained in the 1979 Annual Book of ASTM Standards, Part 41, "General Test Methods, Nonmetal; Statistical Methods; Space Simulation; Particle Size Measurement; General Laboratory Apparatus; Durability of Nonmetallic Materials; Metric Practice." There are additionally several supporting methods

that provide guidelines for developing computerized laboratory systems to handle data. These are contained in the 1979 Annual Book of ASTM Standards, Part 42, "Emission, Molecular, and Mass Spectroscopy; Chromatography; Resinography; Microscopy; Computerized Laboratory Systems."

Besides the test methods used to determine mechanical properties, there are those ASTM standards intended to enhance the understanding of materials behavior. The selection of test specimens for metallographic examination is important in getting to the constituents and structure of metals and alloys. Similarly, the standards for nondestructive testing are important in materials behavior assessment. These are contained in the 1979 Annual Book of ASTM Standards, Part 11, "Metallography; Nondestructive Testing." Rounding out the range of test methods are the standards for chemical analysis of metals and for the sampling and analysis of metal bearing ores. These are contained in the 1979 Annual Book of ASTM Standards, Part 12, "Chemical Analysis of Metals; Sampling and Analysis of Metal Bearing Ores."

In recent years, several technical publications have reported the analysis of trends and concepts in mechanical testing. These studies, in some cases, will be the precursors of test methods. A partial list follows.

(a) The Importance of Microstructural Control to the Processing, Properties, and Service Performance of Materials (Reference ASTM STP 672).

(b) Recent Developments in Technical Testing (Reference ASTM STP 608).

(c) The Use of Computers in the Fatigue Laboratories (Reference ASTM STP 613).

(d) State-of-the-art Review on Developments in the Field of Fracture Mechanics (Reference ASTM STP 632).

The international picture in mechanical testing is becoming structured. Until the recent formation of ISO/TC 164 on Mechanical Testing, this work was being done in separate materials committees within the International Standards Organization (ISO). The new committee is organized in categories of tests: uniaxial, ductility, fatigue, toughness, and hardness. The United States is a participating member, with ASTM Committee E-28 on Mechanical Testing assuming the role of Secretariat for the Subcommittee on Toughness Testing. The responsibilities for administering this activity will be shared with the Metals Properties Council. In fact, the respective ASTM technical committees in consort with the Metal Properties Council will play a vital role in data generation and test method development. This will permit the United States to have an effective input in the international development of mechanical testing standards through the ASTM committee structure.

Standard Reference Materials have a significant role in mechanical properties data programs. For the past three years, an ASTM-NBS Research Associate Program for Standard Reference Materials for Metals has been operating at the Bureau. This program to date has issued 49 Standard Reference Materials (SRMs) with Certificates of Analysis, and work is under way to certify 25 additional metals--aluminum alloys, stainless steels, cast iron, nickel-copper alloys, and others. This program, initially launched through contributors from industry, is now on a self-sustaining basis and is expected to grow in the future. The role it will play in mechanical properties data programs that may develop in coming years is difficult to project. ASTM plans to continue to sponsor Research Associate Programs at the Bureau, as it also intends to participate in data programs wherever its resources are needed.

Recommendations on the Development of Test Methods Measuring Mechanical Properties

Data centers can and should interact with test method programs, whenever possible, on a structured basis. Such liaisons have many positive aspects such as:

1. Assistance to design engineers toward better products.
2. Better introduction of the state-of-the-art parameters into the design process.
3. Better assessment of what material properties need more rigorous definitions and test methods. A mechanism should be developed to coordinate the nature of availability of standard test methods. This compilation probably should be updated annually in hard-copy form and should be made computer-searchable and updated as soon as changes or additions are made. The basic concept would be a listing of the material to be tested, the test, and the standard or reference number.
4. Quicker identification of needs for new test methods.
5. Increased availability of data appraised in the course of test method development.

5. COMPUTERIZING A MECHANICAL-PROPERTIES DATA SYSTEM

This chapter presents a generalized framework of philosophy within which to construct and operate a computerized system for the management of mechanical properties data. Technical details for the implementation of the system would have to be worked out on an individual basis, but there is no doubt that the technology exists for successful implementation. The limiting factors in operating such a system are, in fact, largely political and psychological rather than technical. Prime necessities for the success of a system are its ability to procure data from various sources and its ability to provide scientists and engineers in the field with effective and rapid service.

Before proceeding to general recommendations concerning the desirable characteristics of such a data base, several preliminary considerations should be emphasized.

- First, as is emphasized in this report, the field of mechanical properties is varied and vast. An attempt to establish and operate a single system to store and disseminate all mechanical properties data for all materials is bound to fail. Several specialized systems could be operated much more efficiently.
- Second, the management and primary direction of such systems should be placed in the hands of materials experts actively working in the field of mechanical properties. This step would assure relevance of the priorities of the data system to the needs of the user community. Computer experts should be actively and constantly consulted to allow use of the latest developments in computer technology. Priorities in the design and operation of the data system should emphasize convenience for the user, not for the computer.
- Third, in developing a data base, care should be taken to include a full identification of the material and test conditions involved in the case. Complete and detailed material identification should be emphasized at the expense of the quantity of data included in the system, as unidentified data are useless.
- Finally, the primary consideration in the design of any system should be flexibility. Needs and emphases change with time, and the system should be capable of growing and evolving to meet these changes. Even specialized, dedicated systems can be called upon to make unexpected modifications. The ease with which these modifications can be made is a prime indicator of the efficacy of the system as a whole.

Two basic considerations that must be addressed before proceeding with the design of any system are (1) the physical form of the data base, and (2) the types of data that should be included. Any system should be capable of handling the results of various types of tests with ease. Thus, the problem of which type of data to use is reduced to the basic and general choice between raw (though verified) experimental data and appraised summary data. Both types can be effectively addressed by a computerized system. Experimental data can become very voluminous, and for that reason they are best handled by automated methods. Such a system also facilitates direct display and analysis of the data.

In terms of usefulness to the data consumer, summary data are probably best represented in hard copy handbooks. However, a prime problem in the administration of such handbooks involves updating the information in the books. Thus, even in this case, a computerized reference base of information should be maintained to provide a single current listing of all information. This computerized system can then be used directly to print the hard copy handbooks. A computerized system is also useful for scanning the behavior of various materials based on input criteria and locating candidate materials for a given application.

Data Input

Actual data input can be accomplished in a variety of ways, as long as two rules are observed. First, accuracy is of primary importance. Second, especially if large amounts of data are involved, efficiency is essential. The old-fashioned system of transcribing the data onto standard forms is as yet unsurpassed in meeting both of these criteria. Appendix C includes some sample forms* used within the Mechanical Properties Data Analysis Center (MPDAC) at Oak Ridge National Laboratory (ORNL). Once the data exist on these forms, they can be entered onto any automated data-processing medium. Input to the system should be accomplished through an editing program capable of checking for inconsistencies in format or terminology, and as complete a check as possible on interrelationships of properties against theoretical models or empirically established rules. New data added to the system should be automatically retrieved and rechecked for accuracy.

Access Methods

To derive maximum efficiency in the use of the data base, the search retrieval program used to query the data base and isolate relevant data for a given application must be interactive in nature. Searching a data base is primarily an iterative process, with both accuracy and efficiency in the search dependent upon the ability of the searcher to carry on an active dialogue with the computer. Since the information involved in a mechanical-properties data base would include both textual and numerical entries, the search program must be able to perform searches on both types of content. The system should allow easy isolation of the raw data from tests meeting the desired criteria, or

*Developed by B. L. P. Booker of Oak Ridge National Laboratory.

quick location of all materials bearing certain summary identification, and should be capable of locating tests based on equalities, or ranges of values, in a given numerical field.

The system should be directly accessible for those users [illegible] familiar with the system on the one hand and should, on the other hand, provide assistance by data-center experts to perform the interactive interrogations for those users who themselves are not familiar with the particular data system.

Data Output

The system should have available three modes of output: on-line for distributed processing, a separate high-speed printer (for large volumes), and computer graphics. A generalized program for output of data in variable format tabular form is essential and should include sorting capabilities, to allow output of the data according to any chosen field or fields, as well as flexible graphical capabilities.

Modern computer graphics can save a great deal of time in distinguishing data trends and can now produce camera-ready copies, thus greatly decreasing drafting costs. Graphics output can be accomplished through the use of hard copy pen-and-ink plotters or through direct on-screen display at CRT graphics terminals.

Data Analysis

Once data are stored in machine-readable form, they can be accessed and analyzed using any of the vast array of existing numerical statistical analysis programs or those developed for specialized analysis within the center, although some interfaces between the data base and existing programs might need to be developed. It would be a tremendous waste of the potential of a computerized system not to include analytical capabilities directly in the system, especially for raw data.

However, techniques for analysis of mechanical properties data are not well standardized, and a mighty array of analytical capabilities would be needed to include all possibilities. Specialization of data centers can decrease this problem somewhat, but it must be kept in mind that different applications require different approaches. Thus, analysis of data should be performed by experts in analysis of the particular mechanical properties.

Recommendations for a Computerized Data System

Considerations involved in development of a successful data system include the following:

1. Several specialized data banks are preferred to a single all-encompassing system.
2. These banks should be directed by materials experts, while consulting with computer experts.

3. Identification of data and accuracy of input should take precedence over volume of data.

4. An interactive, on-line, textual-numerical search and retrieval program is needed.

5. The system should be a dynamic data management tool, not a passive repository, for data. It should include flexible capabilities for analysis and display of data.

6. Uniformity and complete documentation of input data are required.

7. Standardized techniques for analysis of mechanical properties data should be developed where needed.

6. INTERNATIONAL ACTIVITIES

Background

International activities in data accumulation and appraisal have increased since the establishment of the National Standards Reference Data Systems (NSRDS) in the United States. A number of formal governmental programs have been established in several countries, including the United Kingdom, the Soviet Union, Germany, and France. However, the emphasis relative to such data centers continues to be national rather than international in character. The emphasis on national concerns and national programs is historical and probably quite natural in view of the specific needs and concerns of each country. With a shrinking world and the expansion of international commerce and cooperation, there is an increasing need for the sharing of numerical data across political boundaries.

Nevertheless, the problems of providing information on a compatible basis for international use are considerable because of the problems outlined in previous chapters on appraisal, standard measurement techniques, and definitions that become aggravated when crossing international boundaries. Even the composition of alloys and their designations differ significantly. The determination of appropriate equivalent values of composition offers a significant challenge. While the need for equivalents has been addressed, and conversion charts, data sheets, and equivalent lists have been developed, the general feeling is that the equivalency approach is not totally satisfactory.

The International Standards Organization (ISO) through its committees as well as bilateral arrangements between corresponding activities in the United States and abroad are addressing elements of the above-named problems. From an international viewpoint, the problem of uniformity and quality of input may be considerably greater than problems of retrieval and dissemination in the future. Current communications technology, as well as impending developments in technology and networking, should facilitate the coordination and exchange from computerized data banks and enhance worldwide access, provided that the input is compatible. Naturally, such worldwide exchange will be enhanced by multilingual capabilities and indexing.

As research and design activities increase abroad and international cooperation develops, there is a special opportunity for input of numerical data on mechanical properties to help meet U.S. needs. Increasingly, data are required to satisfy the substitution of materials for computerized design and even to assess the performance of increased foreign imports.

Available International Data Efforts

A review of available sources with respect to international efforts provides one with the sense that, while significant movements have occurred in the development of national data banks, and international cooperation is increasing, there remains a need for more coordination.

There appear to be a number of general efforts at international coordination. The Advisory Group for Aeronautical Research and Development (AGARD), is a NATO operation involving the United States, United Kingdom, Italy, France, West Germany, Belgium, the Netherlands, Greece, Norway, Canada, and Denmark. The group has a Structures and Materials Panel, which has issued reports on the mechanical properties of aircraft structural materials.

Similarly, The Committee on Data for Science and Technology (CODATA), has been established by the International Council of Scientific Unions (ICSU) and represents some 15 international unions, 17 countries, and two associated organizations. The secretariat is located in Paris. CODATA activities represent an attempt at international coordination and cooperation It provides evaluated data agreed upon internationally in various physical and chemical disciplines. While CODATA projects have not emphasized mechanical properties in the past, an Advisory Panel on Data for Industrial Needs has been established in the recent past. Some of CODATA's activities are being co-sponsored by UNESCO's General Information Program, of which UNISIST is a part.

On a more limited, bilateral basis there have been other international cooperative efforts. For example, the Metal Properties Council (MPC) is in contact with a similar activity in the United Kingdom and exchanges information. Similarly, the Steel Casting Society exchanges information with a corresponding society in the United Kingdom, and the Aluminum Association of America provides a basis for exchange with other countries.

Role of Professional/Technical Societies

A significant source of international activity appears related to the professional and technical societies in the United States. In fact, these societies may provide a major resource for development of appropriate data banks relative to mechanical properties. For example, the American Welding Society (AWS) has an international activity called the American Council of the International Institute of Welding, which provides considerable exchange of information on mechanical properties related to weldments. Similarly, the American Society for Metals (ASM) has substantial international activities involving The Metals Society (London), the Japanese Metals Society, and other countries.

Some professional/technical societies have sponsored specific international groups that have been concerned with mechanical properties associated with specific operations, for example, relating to the drawing of metals. Originally sponsored by ASTM, an international deep drawing group was established involving a number of countries. This group has defined the mechanical properties relating to the deep drawing of metals and is now associated with the Metals Fabrication Technical Division, thus maintaining a continuing interest.

The professional/technical societies also may represent a major resource in the dissemination of new information across international borders, both with respect to what is available and with respect to an alert on new approaches to

mechanical behavior and the development of a background to better understand the applications of numerical data bases.

Government Activities

Many of the data centers, such as the Alloy Design Data Base of NASA, in cooperation with the Soviet Union, as well as some of the nuclear data developed by Oak Ridge National Laboratory, include mechanical-properties data on space and nuclear materials, originating from many countries.

It would seem worthwhile to explore the possibilities for more general participation and proper identification of the use or constraints of such government sponsored data bases. Appropriate relaxation of constraints on distribution to make the data bases sponsored by the various government agencies more available on an international basis should be studied.

Private Industries and Industrial Associations

Mechanical-properties data accumulated and distributed by private companies, as well as industrial associations (e.g., the Aluminum Association of America and the Copper Development Association) represent an important potential for international cooperation, and in fact, some interactions already exist. As is true in the United States, many of the large industrial organizations in Europe concerned with the production of materials and their behavior maintain updated mechanical-properties data bases, particularly those associated with their own products. These sources of data are widely used by practicing engineers in the countries where they are available. Appropriate coordination could represent a worldwide resource.

The Metal Properties Council is another private organization that acts to coordinate and exchange information with its British counterpart. Organized into about 60 technical committees, it represents the potential contribution of technical societies to the input and assessment of data. It provides an overview of the general concern for metals properties and the continuing development of properties to better define materials behavior. As an example, it has been active in coordinating information requests relating to the Aluminum Association of America.

International Computer Networks

There are an increasing number of commercial automated storage and retrieval systems that have been directed toward mechanical properties of materials and/or materials selection. Some of these are being made available on international computer networks, although these mostly provide bibliographic rather than numerical property data at this time. For example, the Copper Development Association's trilingual data system, described earlier, is available through an international network called TYMNET. EURONET is another network established for the dissemination in Europe of data from some 100 data banks, many of which have been produced and are being kept current in the United States. This mode of data dissemination may represent a pattern for the future, particularly as telecommunications technology ties the world closer together.

Recommendations for International Activities

Arrangements involving international cooperation are generally more complex than those associated with national activities, and special coordinating structures are often required to achieve international activity. The following recommendations and observations are made.

1. The general impression is that while international, cooperative activities exist, they are inadequate especially in the area of mechanical properties. It is recommended that an effort be made to increase international cooperation in mechanical-properties data programs.

2. The formation of an international coordination council is recommended to consider, plan, and coordinate development of an eventual international mechanical properties data system. This council would be concerned with the availability and the accumulation of data, the methods of determining such data, and the distribution techniques for such data. It could repeat the pattern of several successful international activities including the International Deep Drawing Group. Also, it could repeat similar successful operations involving the Metal Properties Council. It is recommended that a study be initiated to conduct an in-depth international inventory, similar to the one conducted by NBS for the United States and reported in NBS Special Publication 396-1, entitled, "Critical Survey of Data Sources - Mechanical Properties of Metals."

3. The greatest concern with respect to an international cooperative effort on mechanical properties appears to relate to the uniformity with respect to reporting units, testing methods, material identification, appraisal, data analysis methods, and appropriate qualifications. It appears urgent that some group address the concerns of this input so that the capabilities of telecommunications technology can readily, and without redoing, be joined in an eventual international system.

4. The role of technical and professional societies and trade associations appears particularly significant. Many of these groups already have international activities for technical cooperation with appropriate links. These groups are supported by large user populations and represent immediate user concerns and areas of specialization. It appears that these societies and associations could be most effective in data appraisal and dissemination within the international links they provide.

5. There is evidence that the development of several specialized dedicated systems with respect to mechanical properties is more efficient and user oriented than a single centralized system. It would appear that the role of technical and professional societies concerned with the specialized interests of their members could play an important role in international development of a worldwide automated system.

6. It is essential that notification be made, worldwide, of testing methods and data projects that are in the development stage or under review, in order to reduce unwanted costly duplication of effort and to help assure input to the new work from competent personnel.

7. Where possible, a matrix should be conceived, possibly by NBS in cooperation with CODATA, ISO, ASTM, and others, of (a) test methods for various materials, (b) data for various materials, with the intent of showing where absence of data now exists, and (c) materials designations. A draft of the International Numbering System (INS) has been prepared by ISO. The need for a clearinghouse for alloy designations should be studied further.

APPENDIX A

PANEL ON MECHANICAL PROPERTIES DATA FOR METALS AND ALLOYS
MEETING

July 2-3, 1979
Joseph Henry Building
2100 Pennsylvania Avenue

AGENDA

July 2, 1979

I. INTRODUCTION

1.1 Introductory Remarks, General (Graham)
1.2 Description of NSRDS (Lide)
1.3 NBS Status Report on Mechanical Properties (Rossmassler)

II. Description of Scope of All Mechanical Properties of Metals and Alloys (Graham)

III. Data Programs and Data Needs - Government Agencies

3.1 DOD General Overview (Aines, Persh)
Specific Activity: MPDC & MCIC (Mindlin, Battelle)
3.2 DOE General Overview (Ianiello)
Specific Activity: (Harms, Booker - ORNL)
3.3 NASA Research and NATO Activity (Hirschberg)
NASA Specific Activity (Johnson)
3.4 DOT Bridge Safety (Hartbower)
Specific Subject (Soderquist, Air France Branch, FAA)

LUNCH

IV. Data Programs and Data Needs--Private Sector (Spenders & Contributors)

4.1 University (Corten, U. Ill.)
4.2 Engineering and Design (Westbrook, GE)
4.3 Nuclear Power (Lowe, Babcock & Wilcox)
Coal Gasification and Processing (Black, Cyclops Corp.)
4.4 Automotive (Kasper, Chrysler Corp.)

4.5 Metals Industry
Copper Development Association (Lyman)
Aluminum Association (Mara)
Steel (Fletcher, AISI)

ADJOURN

Dinner - JH Room 240

Film/Slide Show on the "Domestic Information Display System" - Kurt Fritz

July 3, 1979

V. Data Programs and Data Needs - Professional Societies

Metals Properties Council (Graham, Schaefer)
ASTM (Stremba)
ASME (Brister)
Association of American Railroads (Harris)

Open Discussion

Adjourn

PANEL ON MECHANICAL PROPERTIES DATA FOR METALS AND ALLOYS

IN ATTENDANCE

Panel Members	
James A. Graham, Chairman	Deere & Company Technical Center
Herbert L. Black	Cyclops Corporation
M. K. Booker	Oak Ridge National Laboratory
Paul Brister	Babcock & Wilcox
Herbert Corten	University of Illinois
Stewart Fletcher	American Iron and Steel Institute
Ron Langraf	Ford Motor Co.
Joseph F. Libsch	Lehigh University
Art Lowe	Babcock & Wilcox
W. J. Harris	Association of American Railroads
Adolph Schaefer	Metal Properties Council
Henry Stremba	American Society for Testing and Materials
Other Attendees	
Andrew A. Aines	Department of Defense
Joel Abrams	University of Pittsburgh
William Bedesen	Exxon Research & Engineering
Joseph Blue	Department of Defense
Norman Cottrell	Environmental Protection Agency
W. O. Harms	Oak Ridge National Laboratory
Carl Hartbower	Department of Transportation
Marvin Hirschberg	NASA - Lewis Research Center
Lewis Ianniello	Department of Energy
Joseph Innes	Department of Transportation
Robert Johnson	Johnson Spacecraft Center
Arthur Kasper	Chrysler Corporation
David R. Lide, Jr.	National Bureau of Standards
Paul Mara	Aluminum Association
Hassel Ledbetter	National Bureau of Standards
Stuart Lyman	Copper Development Association
Helen Ondik	National Bureau of Standards
G. S. Frohnsdorff	National Bureau of Standards
Harold Mindlin	Battelle Columbus Laboratories
Jerry Persh	Department of Defense

Other Attendees

Stephen S. Rossmassler	National Bureau of Standards
James Smarsh	Department of Defense
Gilbert Shockley	Reynolds Metals Co.
Joseph Soderquist	Federal Aviation Administration
Jack Westbrook	General Electric Research & Development

NRC

Cynthia Carter	Executive Secretary - NDAB
Joseph Lane	National Materials Advisory Board
George Wood	National Research Council

APPENDIX B

MECHANICAL-PROPERTIES DATA SOURCES

1. Abstracting Services

American Society for Metals - Metadex System
American Institute of Aeronautics and Astronautics
Copper Development Association
Aluminum Abstracts (operated by ASM)
National Technical Information Service
Defense Documentation Center (includes classified documents)
Rare Earth Information Center (operated at Iowa State University for the rare-earth industry)
Chemical Abstracts
Smithsonian Scientific Information Exchange

2. Numerical Data Compilation Programs

General Electric (EMPIS)
Copper Development Association
Metal Properties Council (reports published with data)
ASTM (test methods development, data sometimes included)
ASM (Metals Handbook) (typical data)
DOD (Mil Handbook 5) (minimum values)
DOE (Construction Materials Handbook for Coal Gasification; in preparation at NBS)
(Coal Conversion Systems Technical Data Book; in preparation by the Institute of Gas Technology)
(Other coal conversion data projects)
MPDC, Battelle: Aerospace Structural Metals Handbook
NASA: Alloy Design Data Base
HEDL: Nuclear Systems Materials Handbook (Administered by Hanford Engineering Development Laboratory; limited distribution)
Materials Handbook for Superconducting Applications (NBS)
Rare-Earth Information Center (operated at Iowa State University for the rare-earth industry)
Individual Companies

3. Computerized Numerical Data Bases

Battelle
Metals and Ceramics Information Center
Mechanical Properties Data Center

Oak Ridge National Laboratory
Mechanical Properties Data Analysis Center

MPC Data Management System (being planned)

Nuclear Regulatory Commission
Data Bank at Bethesda (includes proprietary data)

EPRI
Reactor Vessels Materials Data Bank

Industrial Organizations (such as Ford Motor Company and Deere & Company)

4. International Activities*

CODATA, Committee on Data for Science and Technology, ICSU
AGARD, Advisory Group for Aeronautical Research and Development, NATO
ISO, International Standards Organization
ASTM, American Society for Testing and Materials
ASM, American Society for Metals
MPC, Metal Properties Council
CDA, Copper Development Association
PGI, General Information Program, Unesco
AWS
NBS
NASA (Alloy Design Data Base)

*Note: None of these has a major thrust in mechanical-properties data, and several relate only modestly to the subject.

APPENDIX C

EXAMPLES OF MECHANICAL-PROPERTIES DATA INPUT FORMS FOR COMPUTERIZED DATA HANDLING

CHEMISTRY

TA
TI
V
W
ZR

MECHANICAL PROPERTIES DATA STORAGE FORM

WELD BACKGROUND DATA

<   >

1. GENERAL DATA

SOURCE FIELDS	<IP>	____ ; ____ ; __/__/__ ; ____ ; ____
WELD NUMBER	<WNØ>	____
VENDOR	<CØM>	____
LEVEL OF RESTRAINT	<RST>	____
JOINT GEOMETRY	<JG>	____
POST-WELD HEAT TREATMENT	<PWHT>	____
SPECIMEN NUMBERS	<SPNØ>	____

2. BASE METAL INFORMATION

BASE MATERIAL	<MA>	____ PLATE ORIENTATION <ØRP> ____
HEAT NUMBER	<HN>	____
PRODUCT FORM	<PF>	____
SECTION THICKNESS	<TH>	____
SPECIAL COMPOSITION	<SCB>	____
HEAT TREATMENT	<HT>	____

3. FILLER METAL INFORMATION

WELD PROCEDURE	<WPRØCF>	____
		____
TEMPERATURE	<TE>	____ ; (C°)
NUMBER OF PASSES	<PTE>	____ ;
AVERAGE WELD CONDITIONS	<WCF>	____
FILLER MATERIAL	<MAF>	____
FLUX	<FLUX>	____
SHIELD GAS	<SGF>	____
SPECIAL COMPOSITION	<SCF>	____
FERRITE NUMBERS	<FN>	____
FILLER MATERIAL DESCRIPTION	<FMD>	____
HAZ MICROSTRUCTURE	<HAZ>	____
ASTM GRAIN SIZE: HAZ	<HGS>	____ ; WELD METAL <GS> ____ ;

FORM

TYPE OF TEST <TY>

SERIES LABEL <ID>

TEMPERATURE <TE> : (°C)

IRRADIATION DATA:

ENVIRONMENT <EN>

EXPERIMENT NUMBER <EX>

MATERIAL <MA>

IRRADIATION TEMP. <IT> :

HEAT NUMBER <HN>

FLUENCE <FL> :

ALLOY BASE <AB>

REACTOR AND POSITION <RP>

PRODUCT FORM <PF>

HEAT TREATMENT

SPECIMEN DESC.

COMMENTS <CM>

SPECIMEN ORIENTATION CODE <SØ>

SPEED <SP> :

SPECIMEN LOCATION <DG> : (RAD.)

TOTAL FRACTURE ENERGY <FE> :

<X> : (CM)

LATERAL EXPANSION <LE> :

<Y> : (CM)

<Z> : (CM)

FRACTURE APPEARENCE <FA> :

<FD> :

FRACTURE TOUGHNESS PARM. <FP> :

DEPTH OF PRECRACK <PC> : (MM)

LOAD AT <LD> : START OF FAST FRACT. (N) : FRACTURE ARREST (N) : MAXIMUM (N) : GENERAL YIELD (N) :

DEFLECTION TO <DF> : (MM) FAST FRACTURE ; : (MM) MAXIMUM LOAD

ENERGY TO <EG> : (J) ; : (J)

SLOPE ELASTIC PORTION <SL> :

LOAD TIME TRACE <TA> (YES OR NØ)

MECHANICAL PROPERTIES STORAGE FORM

TENSILE

RECORD NUMBER

TEST NUMBER <TN> SPECIMEN NUMBER <NØ> SERIES LABEL

SOURCE FIELD <IP>

TEMPERATURE <TE> (°C)

IRRADIATION DATA:

ENVIRONMENT <EN>

EXPERIMENT NUMBER <EX>

MATERIAL <MA>

REACTOR AND POSITION

HEAT NUMBER <HN>

IRRADIATION TEMP.

FLUENCE

COMMENT

NOMINAL

APPARENT MODULUS

TENSILE PROPERTIES

ULTIMATE

UNIFORM

TOTAL ELONGATION

REDUCTION IN AREA

STRAIN RATE

MECHANICAL PROPERTIES DATA STORAGE FORM

FATIGUE

RECORD NUMBER < >

TEST TYPE <TY> F A T I G U E

TEST NUMBER <TN> SPECIMEN NUMBER <NØ> SERIES LABEL <ID>

SOURCE FIELD <IP> ; ; ; ;

TEMPERATURE <TE> ; (C°)

IRRADIATION DATA:

ENVIRONMENT <EN> EXPERIMENT NUMBER <EX>

MATERIAL <MA> REACTOR AND POSITION <RP>

HEAT NUMBER <HN> IRRADIATION TEMPERATURE <IT> ; (C°)

ALLOY BASE <AB> FLUENCE <FL> ; (N/M^3)

PRODUCT FORM <PF>

SPECIMEN DESC. <SD>

HEAT TREATMENT <HT>

COMMENTS <CM>

ORIENTATION <ØR> STRESS CONCENTRATION <KT> ;

MODE OF CONTROL <MC> MAXIMUM TENSILE STRESS AT $N_F/2$ <TS> ; (MPA)

STRAIN RANGE <ET> ; (%) MAXIMUM COMPRESSIVE STRESS <CS> ; (MPA)

MEAN STRAIN <EM> ; (%) ELASTIC STRAIN RANGE <EL> ; (%)

WAVE FORM <WF> PLASTIC STRAIN RANGE <EP> ; (%)

HOLD MODE <HM> CYCLES TO 1ST DECREASE IN STRESS RANGE <ND> ;

HOLD TIME <TI> ; ; (HR)

RAMP STRAIN RATE <SR> ; (%/S) CYCLES TO 5% RED. IN STRESS RANGE <N5> ;

FREQUENCY <FQ> ; (HZ) CYCLES TO FAILURE <NF> ;

POISSON'S RATIO <PR> ; CYCLES DISCONTINUED <TD> ;

MAXIMUM STRESS RANGE <SMX> ; (MPA)

CYCLES TO MAXIMUM STRESS RANGE <NMX> ;

SATURATION STRESS RANGE <ST> ; (MPA)

CYCLES AT SATURATION STRESS RANGE <NS> ;

SATURATION STRESS AMP AT 0.1 HOLD TIME <SH> ; (MPA)

SATURATION MINIMUM STRESS AMPLITUDE <RS> ; (MPA)

TIME TO FAILURE <RT> ; (HR)

MECHANICAL PROPERTIES DATA STORAGE FORM

RECORD NUMBER < >

CREEP

TEST NUMBER <TNØ> SPECIMEN NUMBER <NØ> SERIES LABEL <ID>

SOURCE FIELD <IP> ; ; ; ;

TEMPERATURE <TE> ; (°C)

ENVIRONMENT <EN>

MATERIAL <MA>

HEAT NUMBER <HN>

ALLOY BASE <AB>

IRRADIATION DATA:

EXPERIMENT NUMBER <EX>

REACTOR AND POSITION <RP>

IRRADIATION TEMPERATURE <IT> ; (°C)

FLUENCE <FL> ; (N/M^3)

PRODUCT FORM <PF>

SPECIMEN DESC. <SD>

HEAT TREATMENT <HT>

COMMENTS <CM>

ORIENTATION <ØR>

STRESS CONCENTRATION <KT> ;

STRESS <ST> ; (MPA)

MIN. CREEP RATE <CR> ; (%/HR)

RUPTURE TIME <RT> ; (HR)

TIME DISCONTINUED <TD> ; (HR)

TOTAL ELONGATION <ET> ; (%)

REDUCTION IN AREA <RA> ; (%)

LOADING STRAIN RATE <LE> ; (%/MIN)

LOADING STRAIN <E0> ; (%)

TRANSIENT CREEP STRAIN <TS> ; (%)

STRAIN TO SECONDARY CREEP <E1> ; (%)

TIME TO SECONDARY CREEP <T1> ; (HR)

STRAIN TO TERTIARY CREEP <E2> ; (%)

TIME TO TERTIARY CREEP <T2> ; (HR)

STRAIN TO THIRD-STAGE CREEP (.2% OFFSET) <ESS> ; (%)

TIME TO THIRD-STAGE CREEP (.2% OFFSET) <TSS> ; (HR)

POINTS FROM CREEP CURVE:

STRAIN (%) <SN> ; TIME (HR) <TI> ;

TYPE OF CREEP CURVE

<TC>

APPENDIX D

ABBREVIATIONS USED

AGARD	Advisory Group for Aeronautical Research and Development
AISI	American Iron and Steel Institute
ASM	American Society for Metals
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CDA	Copper Development Association
CODATA	Committee on Data for Science and Technology
DOD	Department of Defense
DOE	Department of Energy
DS	Data Series (ASTM)
DOT	Department of Transportation
EF	Engineering Foundation
EMPIS	Engineering Materials and Processes Information Service
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration
FMS	Federation of Materials Societies
GE	General Electric
HEDL	Hanford Engineering Development Laboratory
ICSU	International Council of Scientific Unions
INS	International Numbering System
IRI	The Industrial Research Institute, Inc.
ISO	International Standards Organization
MCIC	Metals and Ceramics Information Center
MPC	Metal Properties Council
MPDAC	Metal Properties Data Analysis Center
MPDC	Metal Properties Data Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBS	National Bureau of Standards
NDAB	Numerical Data Advisory Board
NRC	National Research Council
NSRDS	National Standard Reference Data System
ORNL	Oak Ridge National Laboratory
OSRD	Office of Standard Reference Data
PGI	General Information Program
SAE	Society of Automotive Engineers
SRM	Standard Reference Material
STP	Special Technical Publication (ASTM)
U.Ill	University of Illinois
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISIST	A title given to UNESCO's Intergovernmental Program for Cooperation in the Field of Scientific and Technical Information

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